

CLAIMS

What is claimed is:

- 1 1. A method of determining a parameter of interest for a region of an earth
2 formation using a nuclear magnetic resonance (NMR) instrument conveyed in
3 a borehole, the method comprising:
 - 4 (a) producing a static magnetic field in a region including said region of
5 interest;
 - 6 (b) transmitting a sequence of radio frequency (RF) pulses for producing
7 an RF magnetic field in said region, said RF magnetic field having a
8 spatially varying intensity in said region and a direction substantially
9 orthogonal to a direction of said static magnetic field, a subset of said
10 RF pulses further having a pulse length related to zeros of a Bessel
11 function;
 - 12 (c) receiving NMR signals having amplitudes produced by said RF
13 magnetic field; and
 - 14 (d) determining said parameter of interest using said amplitudes.
- 15
1 2. The method of claim 1 wherein said parameter of interest comprises a spin
2 density function.
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- 1 3. The method of claim 1 wherein said NMR signals comprise free induction
2 decay signals associated with said subset of RF pulses.

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1 4. The method of claim 1 wherein said subset of RF pulses comprises tipping
2 pulses, the pulse sequence further comprising a plurality of refocusing pulses
3 associated with said tipping pulses, and wherein said NMR signals comprise
4 spin echo signals.

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1 5. The method of claim 3 wherein determining said parameter of interest further
2 comprises performing an inverse Hankel transform on said signals.

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1 6. The method of claim 5 wherein determining said parameter of interest further
2 comprises using a spatial mapping to map said spin density to a spatial
3 location.

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1 7. The method of claim 4 wherein said sequences of RF pulses are of the form:

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$$[\tau_j - \frac{TE}{2} - (R - TE)_i - TW]_j$$

3 where TE is a time interval between refocusing pulses R, τ_j is a tipping pulse,
4 TW is a wait time, i is the index of the number of refocusing pulses, and j is
5 the index of the number of CPMG (or modified CPMG) sequence acquired for
6 a single tipping pulse.

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1 8. The method of claim 7 wherein determining said parameter of interest further
2 comprises summing the spin echo signals resulting from said sequence of RF
3 pulses over the index j for a selected value of i .

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1 9. The method of claim 8 wherein said summing is a weighted summing.

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1 10. The method of claim 9 wherein determining said parameter of interest further
2 comprises using a spatial mapping to map said spin density to a spatial
3 location.

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1 11. The method of claim 6 further comprising determining spins associated with a
2 portion of the region of interest outside said borehole.

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1 12. The method of claim 10 further comprising determining spins associated with
2 a portion of the region outside said borehole.

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1 13. The method of claim 6 further comprising partitioning said spins into
2 azimuthal sectors.

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1 14. The method of claim 10 further comprising partitioning said spins into
2 azimuthal sectors.

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- 1 15. The method of claim 1 further comprising repeating (a) – (d) for a number of
2 different azimuthal orientations of said instrument.
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- 1 16. The method of claim 15 further conveying said instrument into said borehole
2 on a bottom hole assembly.
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- 1 17. An apparatus for determining a parameter of interest for a region of an earth
2 formation comprising:
3 (a) a magnet for producing a static magnetic field having a direction
4 within the region;
5 (b) a transmitter for transmitting a sequence of radio frequency (RF)
6 pulses for generating a RF magnetic field in said region, said RF
7 magnetic field having a spatially-varying intensity in said region and a
8 direction substantially orthogonal to the direction of the static
9 magnetic field,
10 (c) a processor for controlling said transmitter and defining a subset of
11 said RF pulses to have pulse lengths related to zeros of a Bessel
12 function;
13 (d) a receiver for receiving NMR signals produced by said RF magnetic
14 field; and
15 (e) a processor for determining said parameter of interest from amplitudes
16 of said NMR signals.
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- 1 18. The apparatus of claim 17 wherein said parameter of interest comprises a spin
2 density function.
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- 1 19. The apparatus of claim 17 wherein said NMR signals comprise free induction
2 decay signals associated with said subset of RF pulses.
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- 1 20. The apparatus of claim 17 wherein pulses of said subset of RF pulses are
2 tipping pulses, the pulse sequence further comprising a plurality of refocusing
3 pulses associated said tipping pulses and wherein said NMR signals comprise
4 spin echo signals.
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- 1 21. The apparatus of claim 17 wherein said processor in (e) is configured so as to
2 determine a spin density as a function of said RF field intensity.
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- 1 22. The apparatus of claim 21 wherein said processor is configured to transform
2 said spin density to a spatial location.
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- 1 23. The apparatus of claim 21 wherein said sequences of RF pulses are of the
2 form: $[\tau_j - \frac{TE}{2} - (R - TE)_i - TW]_j$
3 where TE is a time interval between refocusing pulses R, τ_j is a tipping pulse,
4 TW is a wait time, i is the index of the number of refocusing pulses and j is

5 the index of the number of CPMG (or modified CPMG) sequence acquired for
6 a single tipping pulse.

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1 24. The apparatus of claim 17 wherein the same antenna is used for transmitting
2 said RF pulses and receiving said signals.

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1 25. The apparatus of claim 17 wherein said processor in (c) and said processor
2 in (e) are the same.